# Transition from a radial to a 3D buoyancy-driven hydraulic fracture

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Magmatic dikes are a naturally occurring type of fluid-driven fractures (Rivalta et al. 2015) propagating in the lithosphere due to buoyant forces emerging from the density difference between the host material and the injected fluid (more precisely the difference between the gradients of the in-situ minimum stress and the hydrostatic pore-fluid pressure).
The form of such buoyant fractures has been extensively studied in the context of magmatic dikes and shows the appearance of a head-tail structure (Rivalta et al. 2015). 2D plane-strain evaluations highlighted the fact that lubrication flow in the tail is driving the growth of the hydrostatic head (Lister & Kerr 1991; Roper & Lister 2005), which has been confirmed by Germanovich et al. (2014) for the 3D finger-like geometry.
We investigate the 3D transition of a radial hydraulic fracture emerging from a point source towards a buoyancy-driven fracture, focussing on the case of a constant injection rate in homogeneous conditions (homogeneous material properties and buoyancy contrast). We use scaling arguments to characterize the transition and the late time buoyant behavior of the fracture and validate the findings with the fully coupled planar 3D hydraulic fracture growth solver PyFrac (Zia & Lecampion 2020).
Our results confirm a characteristic transition time / length scale from a radial to a buoyant fracture depending on a single dimensionless parameter. The same parameter can be used to predict the fractures overrun (maximum breadth / stabilized breadth). A second, very slow transition takes place between the elongated fracture and the late time fully-developed 3D head-tail structure (similar to the solution of Germanovich et al. (2014)). Our simulations support the appearance of a 3D toughness dominated head structure. They also confirm the importance of the viscous tail as the driving mechanism for the dynamics of such a 3D Weertman's pulse (form of the head). We quantify how and when the transition from a radial to a buoyant fracture takes place, and it's implications on the late time behavior.

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